



Whole-Building Energy Modeling with OpenStudio



**Commercial Building
Energy Alliance Webinar**

**Nicholas Long, NREL
David Goldwasser, NREL**

August 24, 2011

Outline

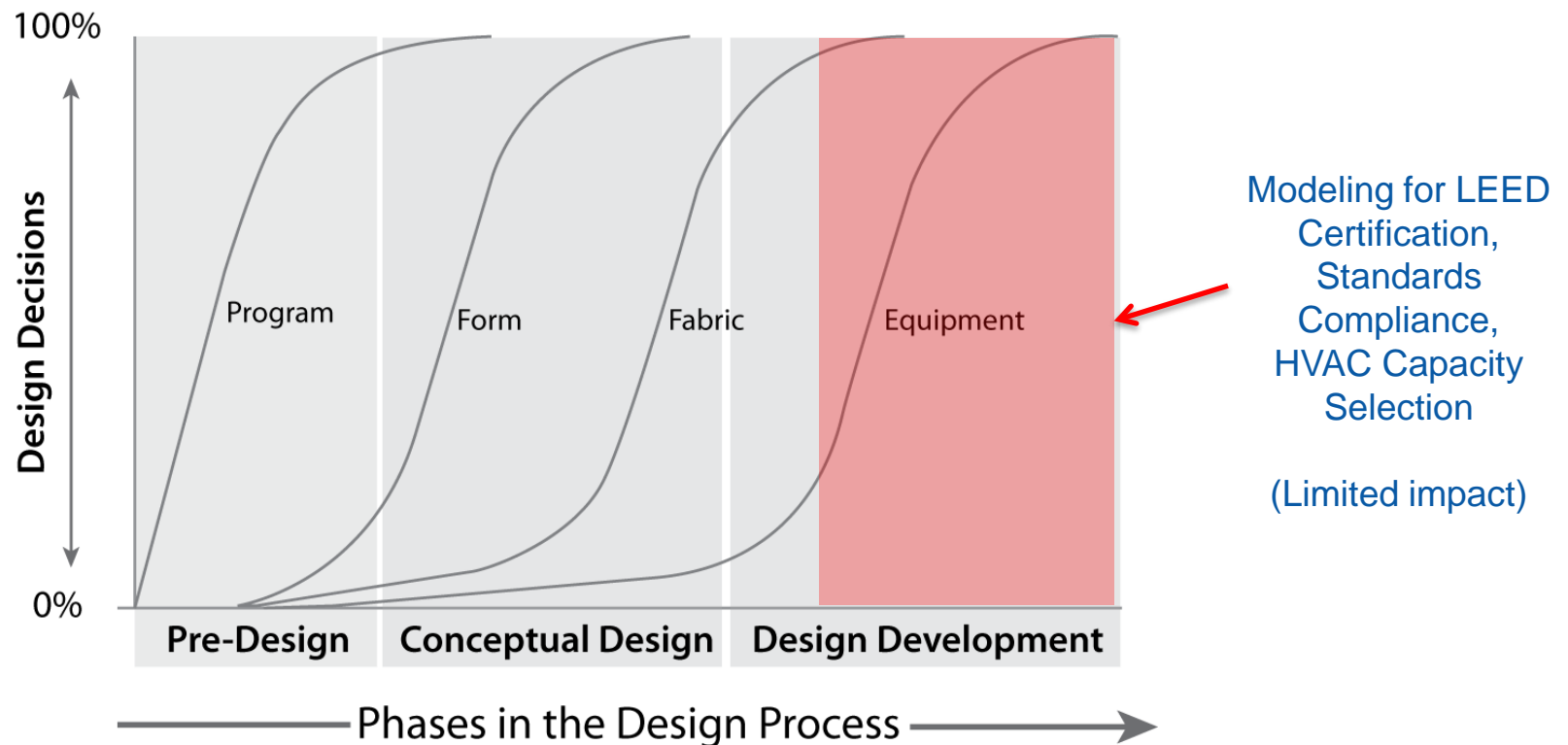
- Energy Modeling Introduction
- OpenStudio Demo (Modeling for Retrofits)
- Typical Barriers to Using Simulation
- Conclusions and Questions

Energy Modeling Introduction

The Design Process

Typical Use of Energy Modeling

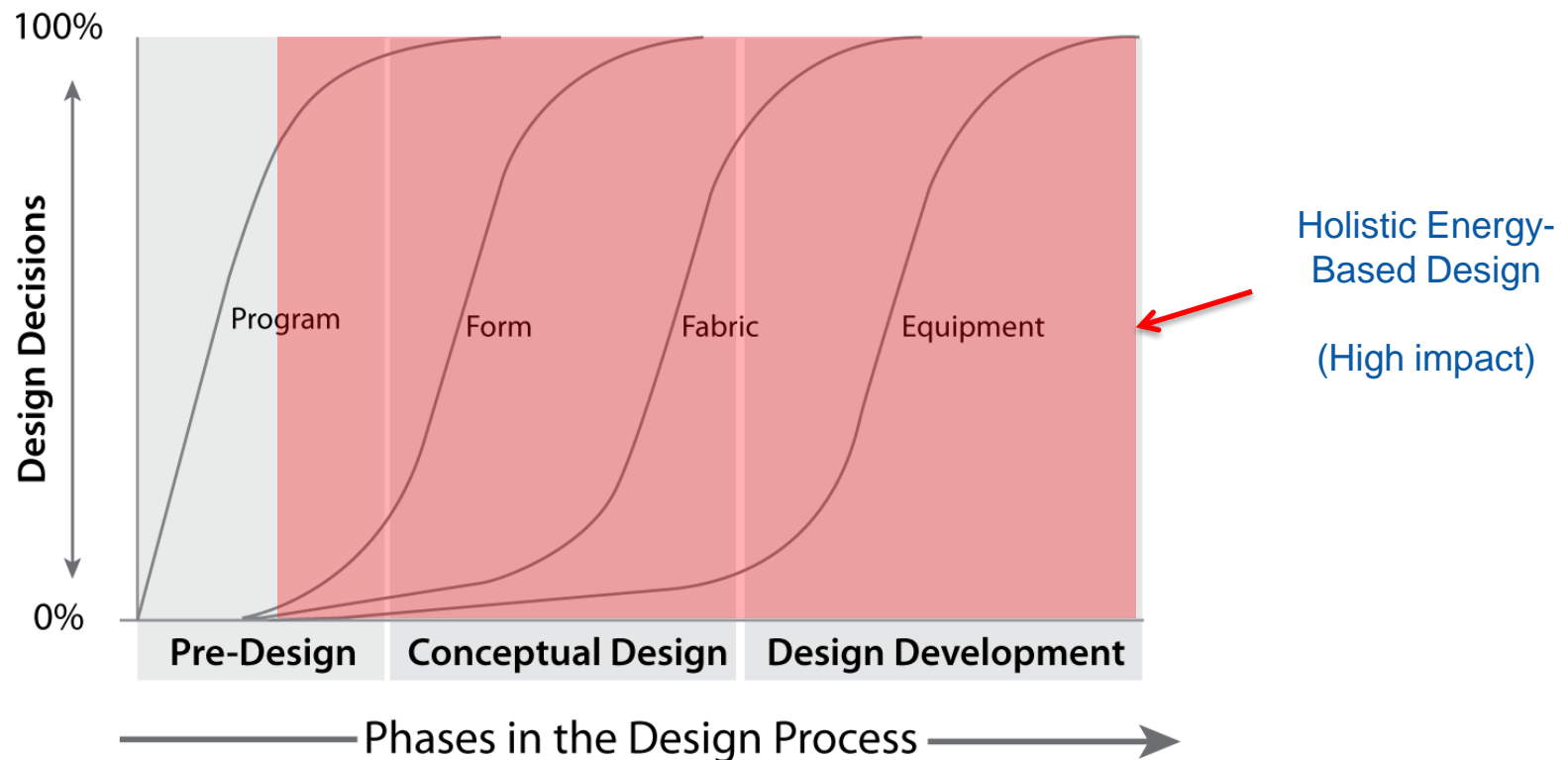
Energy efficiency is often not a primary consideration during the building design process, and evidence from modeling and energy simulation is often used only to get a LEED certification if it is used at all.



Source: *A Handbook for Planning and Conducting Charrettes for High-Performance Projects, Second Edition*, 2009, Figure 1.

Effective Use of Energy Modeling

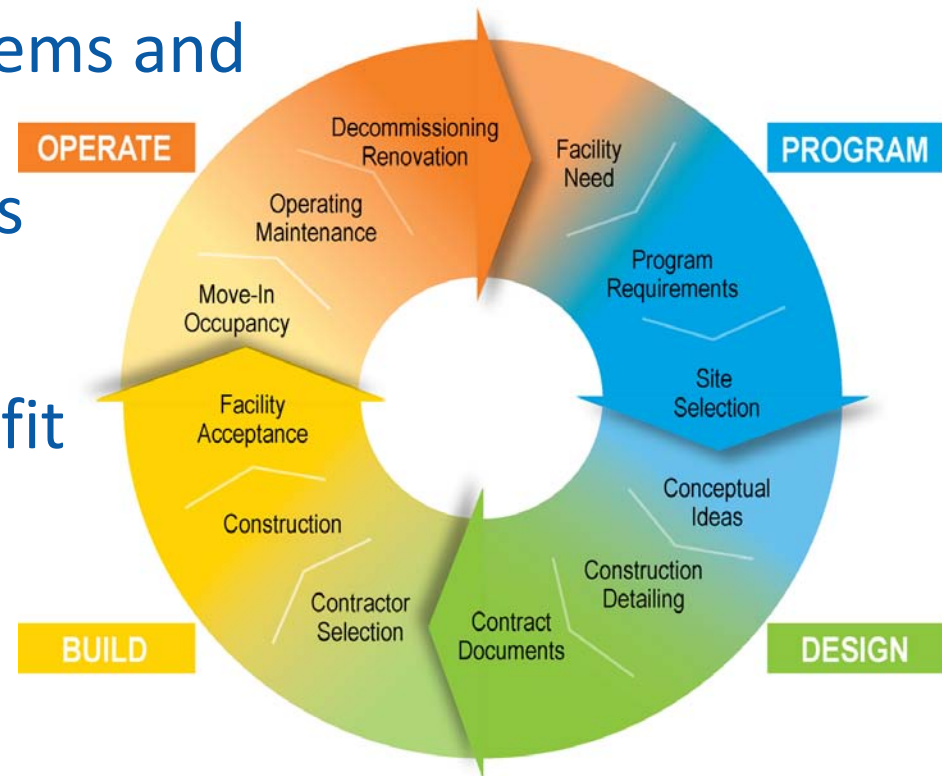
Energy modeling needs to be about more than getting a checkbox on a certification.



Source: *A Handbook for Planning and Conducting Charrettes for High-Performance Projects, Second Edition*, 2009, Figure 1.

Why Use Energy Simulation?

- Inform energy decisions from the earliest phases
- Help the design team and owner focus on energy-use reduction
- Assess predicted performance with project goals
- Size renewable energy systems and determine contribution
- Evaluate design alternatives throughout programming, design, construction, operation—as well as retrofit
- Simulation is cheaper than constructing the wrong building!



Credit: DOE

What Can Energy Simulation Do for My Building?

- Compare different design or retrofit options
 - Load calculations
 - Energy performance
 - Peak demand
 - Cost-benefit calculations
- Simulate complex technologies
 - Naturally ventilated, passive buildings
 - Thermal energy storage
 - Daylighting
 - Overheating in unconditioned spaces
 - Advanced controls operation
- Heating, cooling equipment design
- Dynamic response
- Regulatory compliance
- Green building ratings

Why Use Energy Simulation for Retrofit Projects?

- Evaluate technology packages
 - Lighting Technology
 - Window VLT
 - Daylighting controls
 - Envelope Changes
 - Windows
 - Shading devices
 - Skylights
- Analyze specific components
 - HVAC performance
 - Operational characteristics
 - On-site renewables
 - Internal load reductions

Simulation vs. Operating Energy

DOE's analysis tools have been critical for supporting decision-making in the design and operation of buildings.

Focus on energy efficiency, then renewable energy.

Compared to simulations, real buildings typically:

- Use more energy
- Produce less power
- Have worse controls
- Have more varied schedules
- Have more occupant complaints

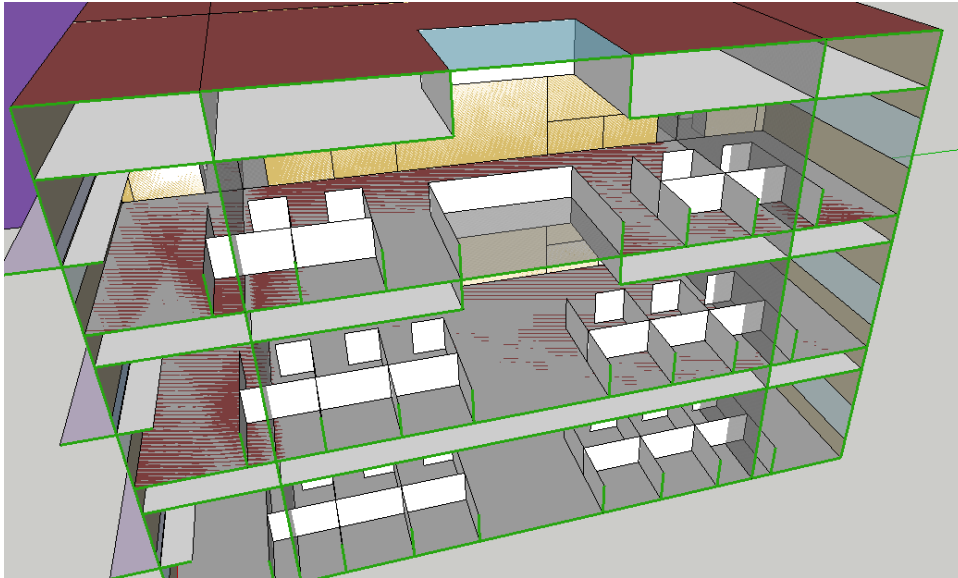
Garbage in, garbage out.



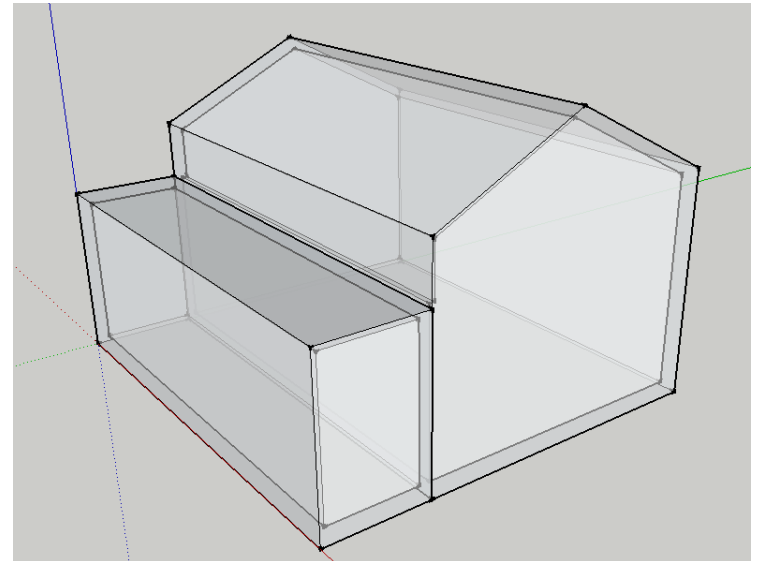
Credit: NREL PIX

Thick Wall vs. Thin Wall

- Most energy modeling occurs on “Thin Wall” vs. “Thick Wall” models.



VS



Credit: David Goldwasser / NREL

Energy Modeling Introduction

Skylight Analysis

Skylight Analysis:

Daylighting for Large Retail Building

133,275 ft² energy model

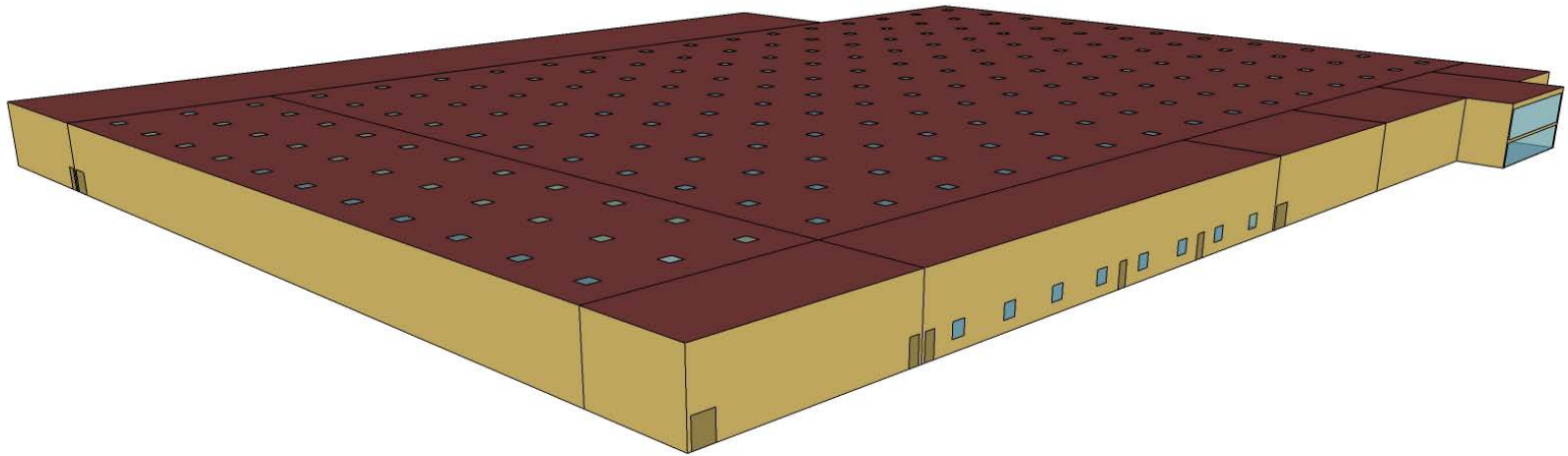
Add skylights and lighting controls (103,750 ft² total)

- Skylights: modeled 1% to 5% skylight to floor area (SFA) ratio in 1% increments
- Skylight properties: U-Value = 0.82, SHGC = 0.49, VLT = 0.65
- Lighting control: one sensor per zone, 50 footcandle set point, continuous dimming to off

Investigate annual energy for models in 7 different climate zones

Skylight Analysis:

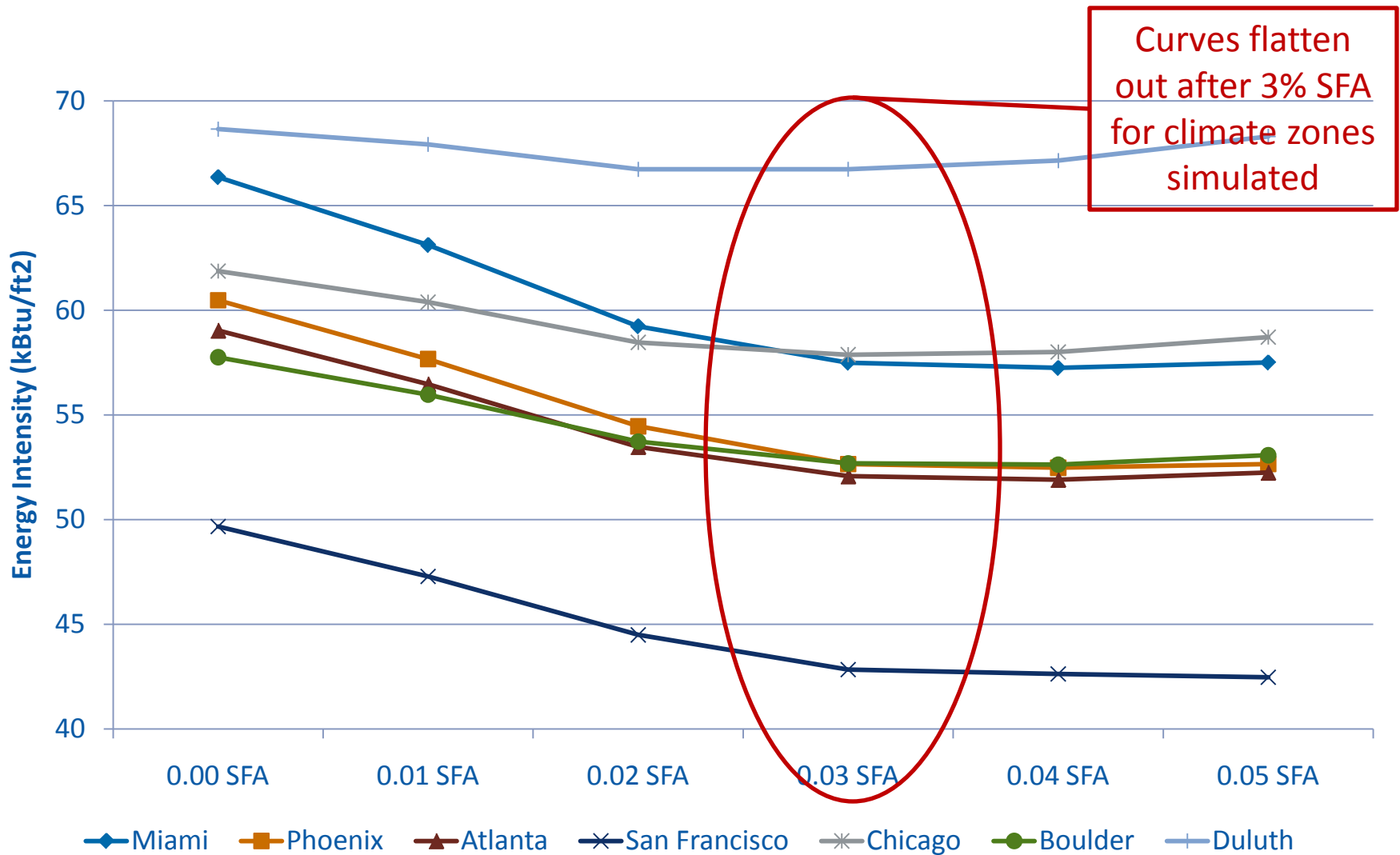
3% SFA Energy Model Rendering



Credit: Eric Bonnema / NREL

Skylight Analysis:

Determining SFA Ratio to Report

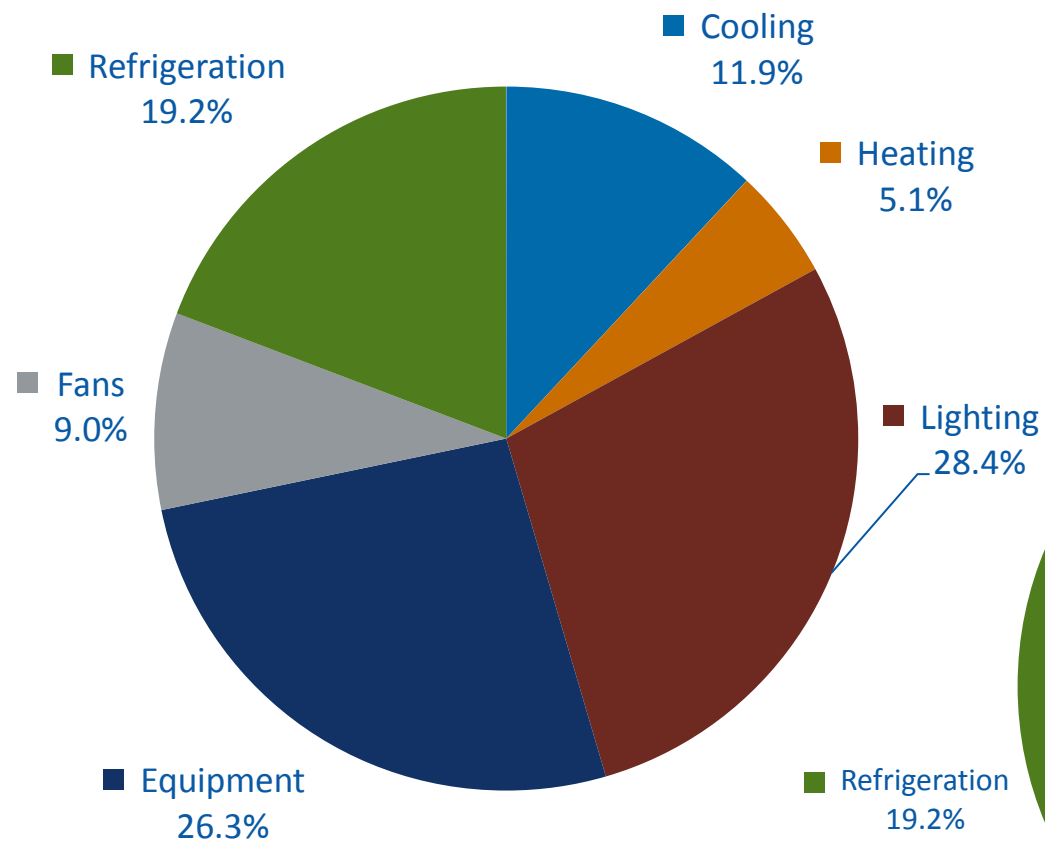


Credit: Eric Bonnema / NREL

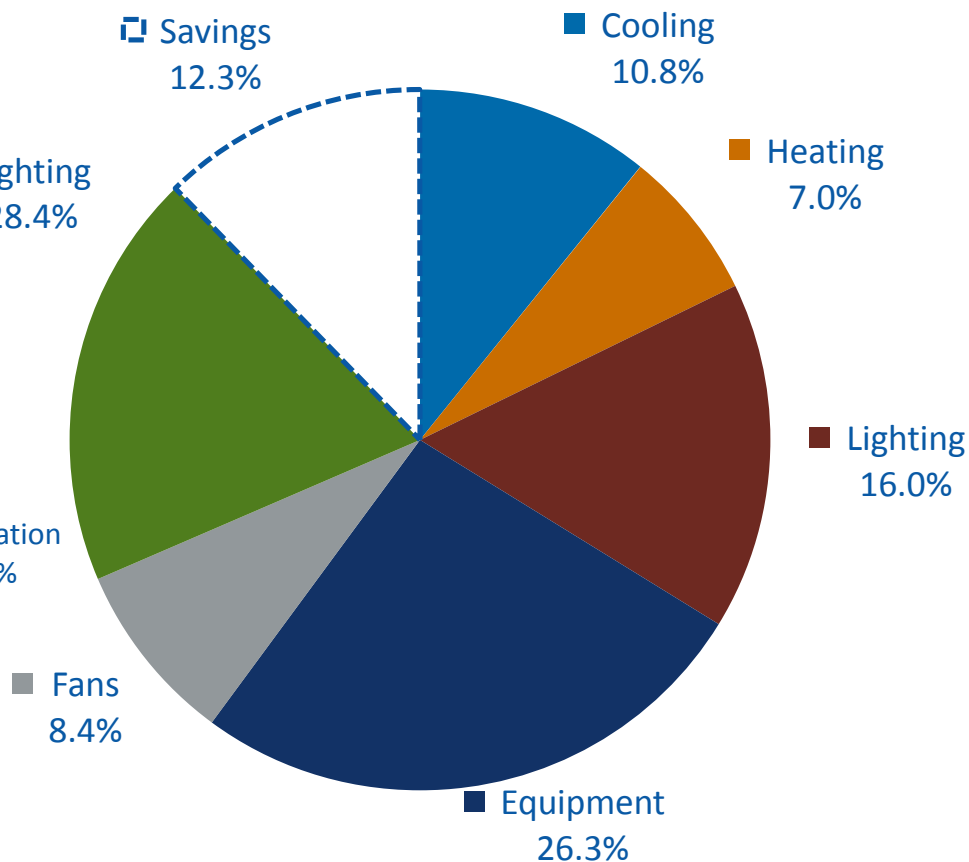
Skylight Analysis:

Energy Savings for Atlanta, Climate Zone 3A, Hot and Humid

Baseline Model



3% SFA Daylit Model



Credit: Eric Bonnema / NREL

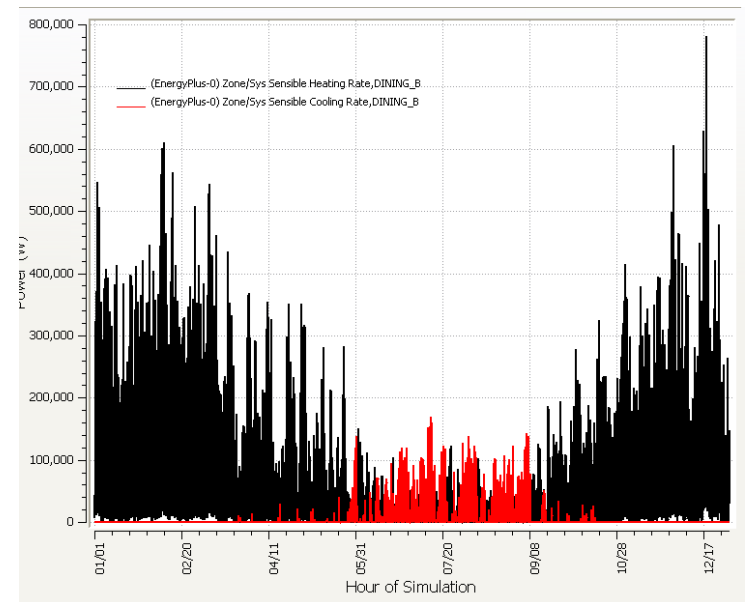
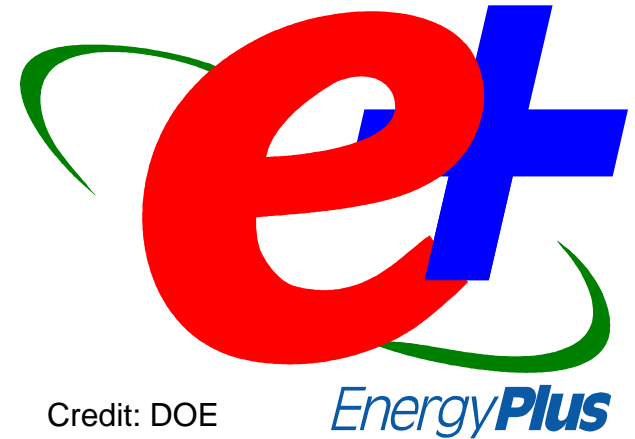
Energy Modeling Introduction

Tools – EnergyPlus and OpenStudio

What is EnergyPlus?

- Fully integrated building, envelope, HVAC, water, and renewables simulation program
- One of the most robust whole-building energy simulation tools available in the world today
- Enables integrated energy performance analysis of low-energy technologies in commercial and residential buildings including on-site generation and renewable energy systems
- Interfaces available from private sector developers
- Free
- Windows 7/XP, Linux & Mac

<http://www.energyplus.gov>



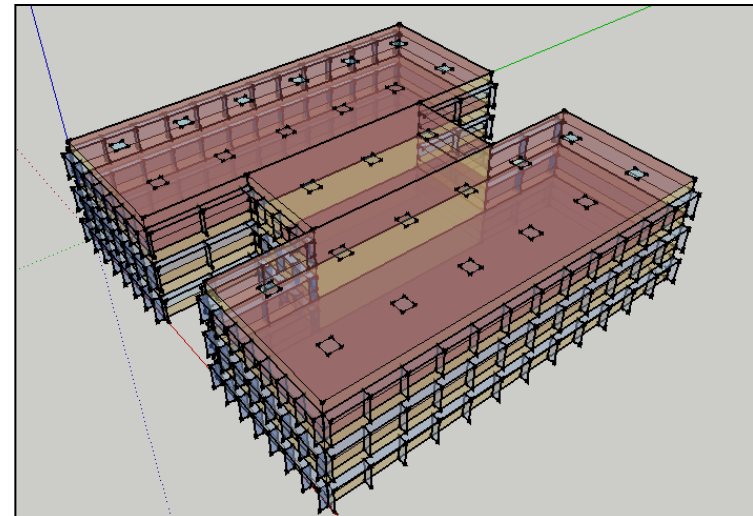
What is OpenStudio?

OpenStudio is:

- An EnergyPlus/Radiance framework for national labs, code/standard officials, and third parties to easily extend the base capability of EnergyPlus for diverse purposes
- Free
- Open source
- Cross-platform



Credit: Erica Augustine / NREL



Credit: David Goldwasser / NREL

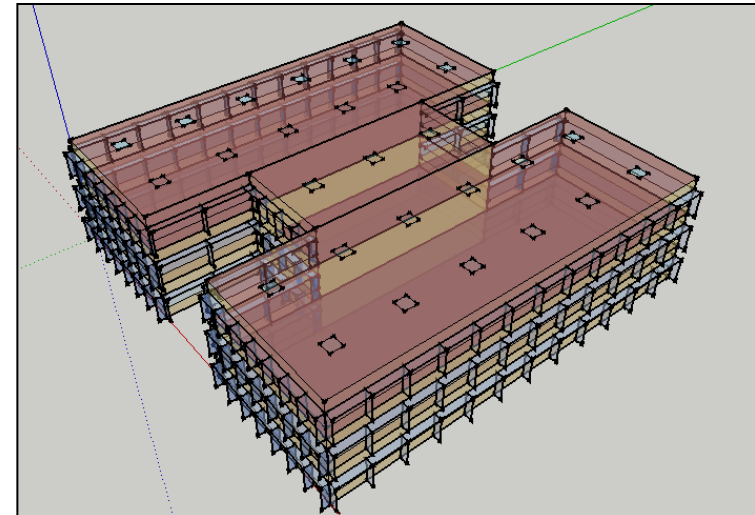
What does OpenStudio include?

- A plug-in to Google SketchUp
 - SketchUp has more than 2,000,000* users per week worldwide
 - ~55% of these users are architects
 - Mature product with a well-defined interface for extension
- Other front ends
 - Results visualization
 - Simple HVAC SystemOutliner
 - ModelEditor
 - RunManager
- Back-end functionality
 - Scripting interfaces
 - Workflow management
 - Pre- and post-processing capabilities
 - Component libraries (e.g. MELs)
 - Interoperability with other engines for analysis

* Usage statistics released by Google in 2011.



Credit: Erica Augustine / NREL

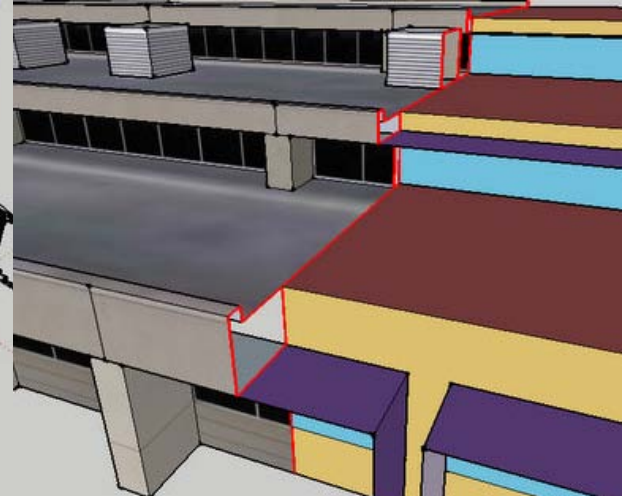
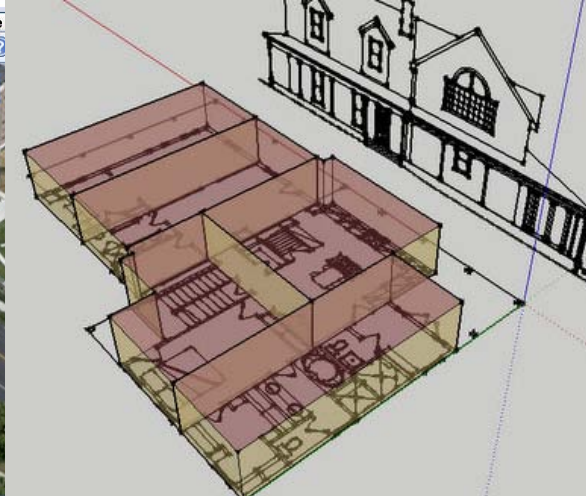
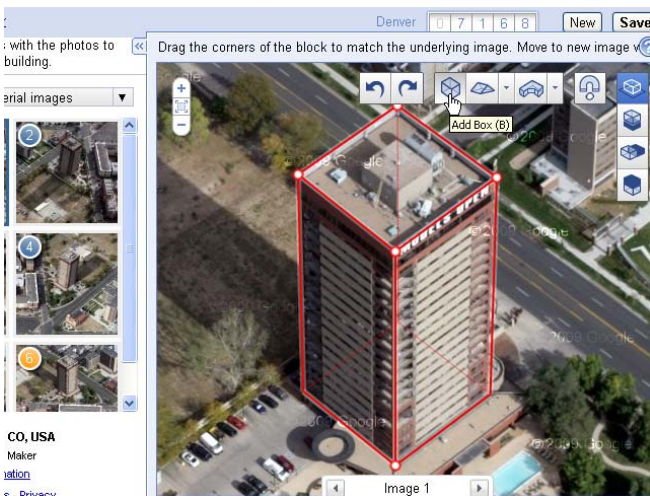
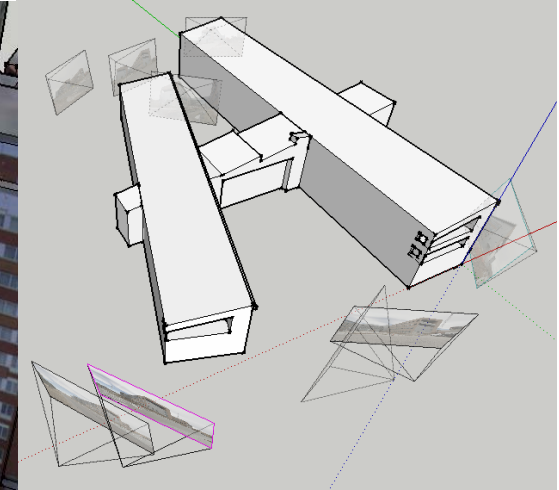


Credit: David Goldwasser / NREL

OpenStudio Demo (Modeling for Retrofits)

OpenStudio Demo

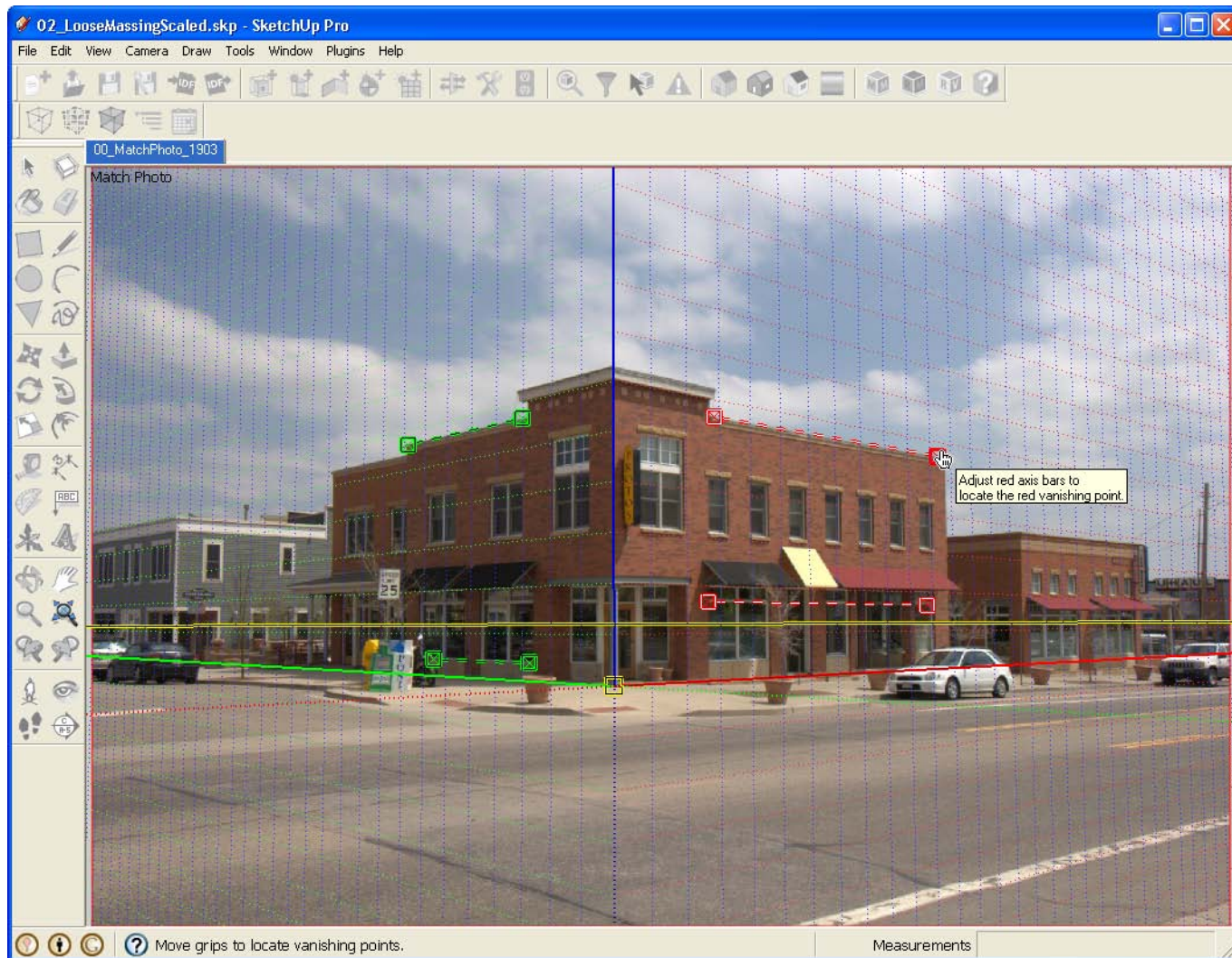
Geometry Input Methods



Credit: David Goldwasser / NREL

OpenStudio Demo

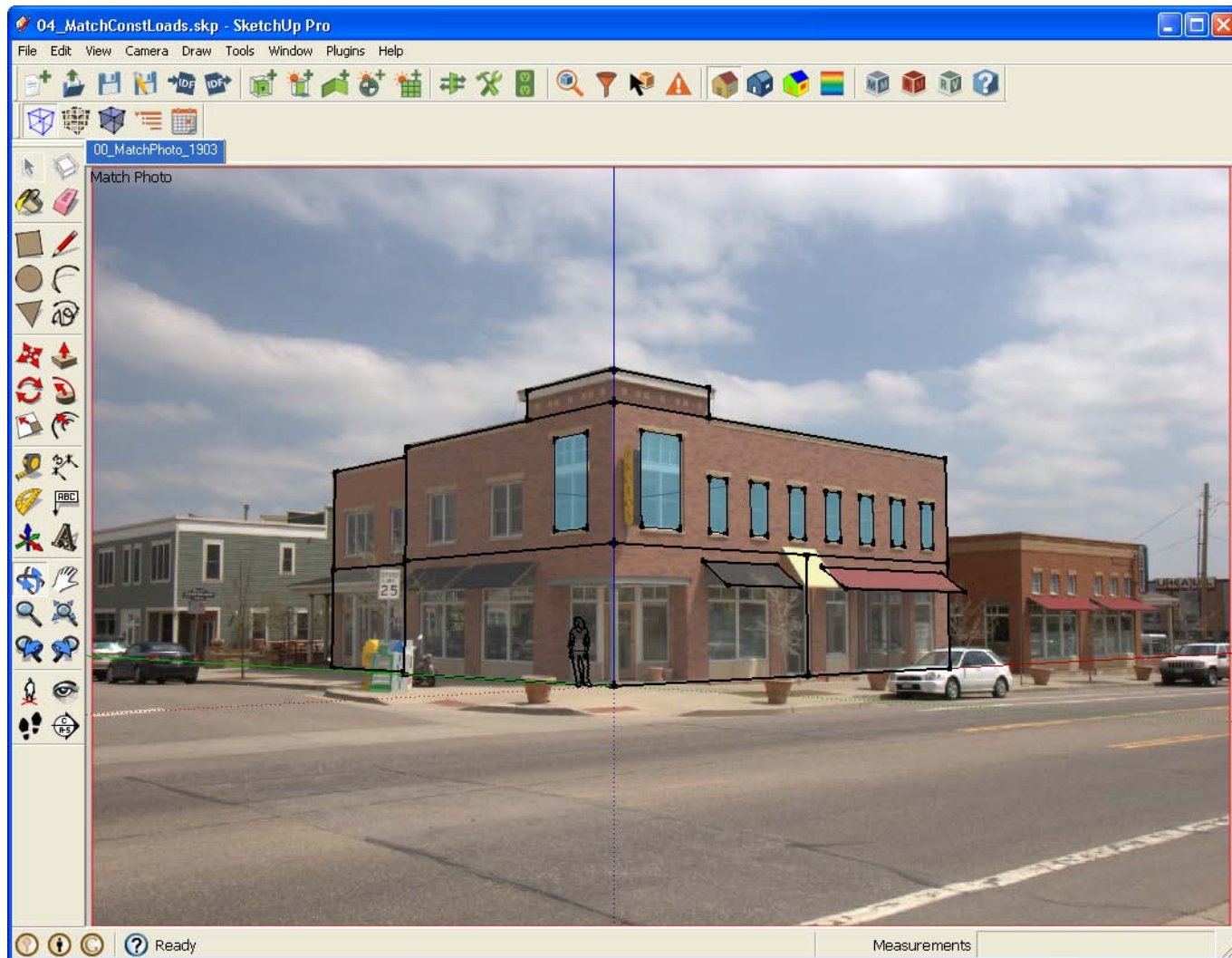
Geometry From Photos of Existing Buildings (Calibration)



Credit: David Goldwasser / NREL

OpenStudio Demo

Geometry From Photos of Existing Buildings (Modeling)



Credit: David Goldwasser / NREL

OpenStudio Demo

Vintage and Climate-Zone-Specific Constructions

The image shows a screenshot of the SketchUp Pro interface with the 'Default Constructions' dialog box open. The dialog box is titled 'Default Constructions' and has a 'Construction Sets (help)' dropdown menu. The 'Default Construction Set' is set to '1980-Post_ClimateZone 5b (fsr)'. The dialog box lists various construction sets for different building components, including Exterior Floor, Exterior Wall, Exterior Roof, Exterior Window, Exterior Door, Interior Floor, Interior Wall, Interior Ceiling, Interior Partition, Interior Window, Interior Door, Glass Door, Skylight, Tubular Daylight Dome, and Tubular Daylight Diffuser. A red box highlights a list of construction sets on the right side of the image, which are organized by climate zone and construction type. The list includes:

- 2009-LowEnergyCase_ExtWall_Mass_ClimateZone 1
- 2009-LowEnergyCase_ExtWall_Mass_ClimateZone 2
- 2009-LowEnergyCase_ExtWall_Mass_ClimateZone 3
- 2009-LowEnergyCase_ExtWall_Mass_ClimateZone 4
- 2009-LowEnergyCase_ExtWall_Mass_ClimateZone 5
- 2009-LowEnergyCase_ExtWall_Mass_ClimateZone 6
- 2009-LowEnergyCase_ExtWall_Mass_ClimateZone 7-8
- 2009-LowEnergyCase_ExtWall_Mass_ClimateZone_alt-res 1
- 2009-LowEnergyCase_ExtWall_Mass_ClimateZone_alt-res 2
- 2009-LowEnergyCase_ExtWall_Mass_ClimateZone_alt-res 3
- 2009-LowEnergyCase_ExtWall_Mass_ClimateZone_alt-res 4
- 2009-LowEnergyCase_ExtWall_Mass_ClimateZone_alt-res 5
- 2009-LowEnergyCase_ExtWall_Mass_ClimateZone_alt-res 6
- 2009-LowEnergyCase_ExtWall_Mass_ClimateZone_alt-res 7
- 2009-LowEnergyCase_ExtWall_Mass_ClimateZone_alt-res 8
- 2009-LowEnergyCase_ExtWall_Metal_ClimateZone 1-3
- 2009-LowEnergyCase_ExtWall_Metal_ClimateZone 4-8
- 2009-LowEnergyCase_ExtWall_SteelFrame_ClimateZone 1-3
- 2009-LowEnergyCase_ExtWall_SteelFrame_ClimateZone 4-8
- 2009-LowEnergyCase_ExtWall_WoodFrame_ClimateZone 1-4
- 2009-LowEnergyCase_ExtWall_WoodFrame_ClimateZone 5
- 2009-LowEnergyCase_ExtWall_WoodFrame_ClimateZone 6-8
- 2009-LowEnergyCase_ExtWindow_ClimateZone 1
- 2009-LowEnergyCase_ExtWindow_ClimateZone 2
- 2009-LowEnergyCase_ExtWindow_ClimateZone 3
- 2009-LowEnergyCase_ExtWindow_ClimateZone 4-5
- 2009-LowEnergyCase_ExtWindow_ClimateZone 6
- 2009-LowEnergyCase_ExtWindow_ClimateZone 7-8
- 2009-LowEnergyCase_ExtWindow_ClimateZone_alt-res 4-5

The background of the SketchUp Pro window shows a 3D model of a building with a red roof and blue windows. The status bar at the bottom of the window indicates 'Drag to orbit. Shift = Pan' and 'Measurements'.

Credit: David Goldwasser / NREL

OpenStudio Demo

Vintage and Space-Type-Specific Internal Loads

The screenshot shows the 'Zone Loads' dialog box in OpenStudio. The 'Zone Loads' section has a dropdown menu with the following list of zone load profiles:

- 1979-Pre_FullServiceRestaurant_Dining
- 1979-Pre_FullServiceRestaurant_Kitchen
- 1979-Pre_FullServiceRestaurant_Kitchen
- 1980-Post_FullServiceRestaurant_Dining
- 1980-Post_FullServiceRestaurant_Kitchen
- 2004_FullServiceRestaurant_Dining
- 2004_FullServiceRestaurant_Kitchen
- 2009 ClimateZone 1-3_FullServiceRestaurant_Dining
- 2009 ClimateZone 1-3_FullServiceRestaurant_Kitchen
- 2009 ClimateZone 4-8_FullServiceRestaurant_Dining
- 2009 ClimateZone 4-8_FullServiceRestaurant_Kitchen
- Attic

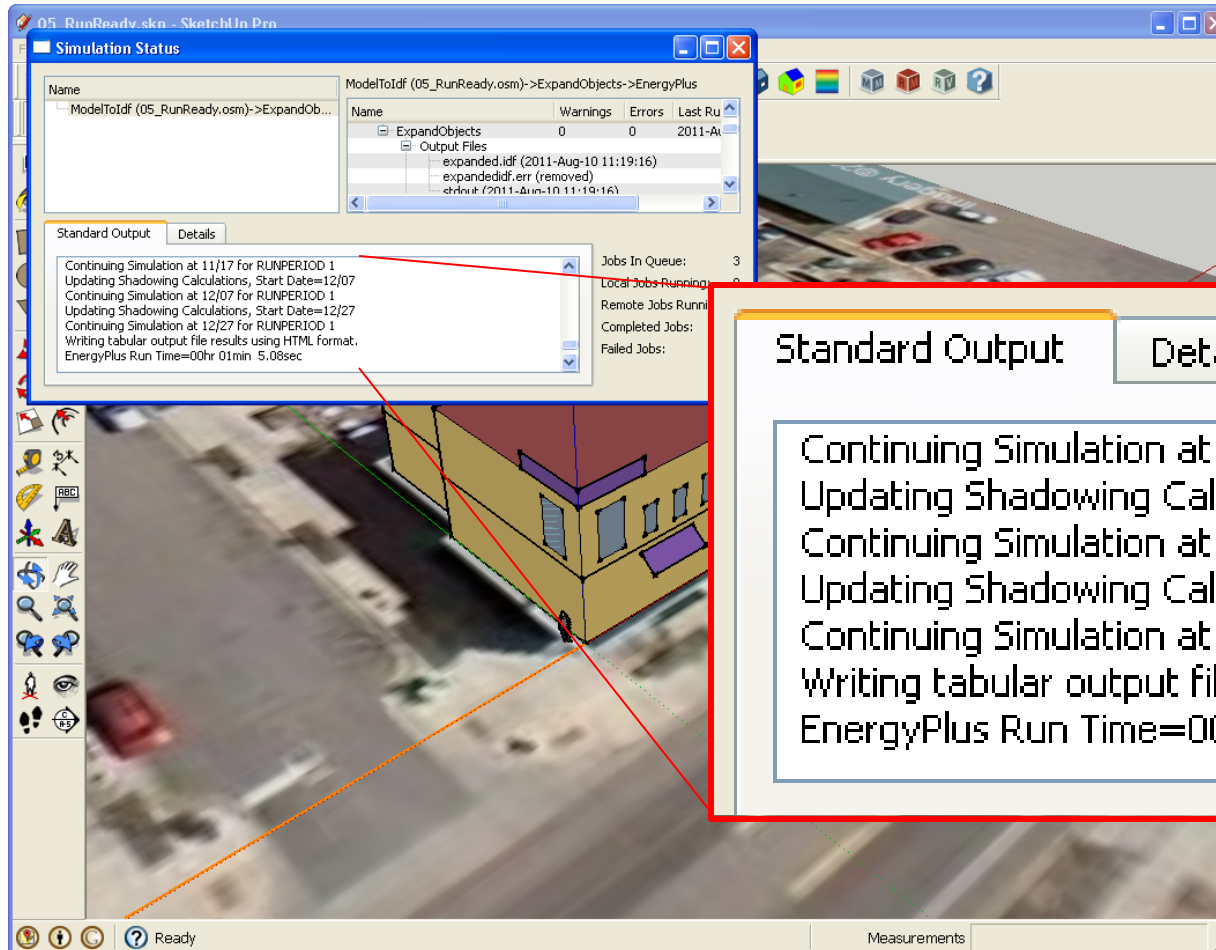
The '2009 ClimateZone 4-8_FullServiceRestaurant_Dining' profile is selected. The 'People per Zone Floor Area (Number of People/1000 ft)' is set to 2.77. The 'Lighting Power Density (W/ft²)' is set to 5.6. The 'Electric Equipment Power Density (W/ft²)' is set to 0.0. The 'Gas Equipment Power Density (W/ft²)' is set to 0.0. The 'Outdoor Air per Person (cfm/person)' is set to 21.19. The 'Outdoor Air per Area (cfm/ft²)' is set to 0.0. The 'Infiltration Rate (ACH)' is set to 2.41. The 'HVACTemplate:Zone:IdealLoadsAirSystem' is checked. The 'HVACTemplate:Thermostat' is set to 'FullSurfaceRestaurant Thermostat (Dining)'. The 'Apply to Entire Model' button is highlighted.

A red box highlights the list of zone load profiles, and a mouse cursor points to the '2009 ClimateZone 4-8_FullServiceRestaurant_Dining' profile.

Credit: David Goldwasser / NREL

OpenStudio Demo

Running the EnergyPlus Simulation Through OpenStudio RunManager

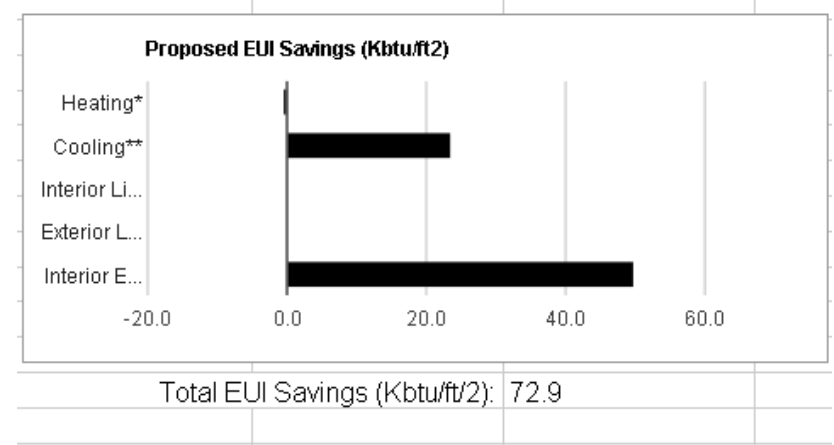
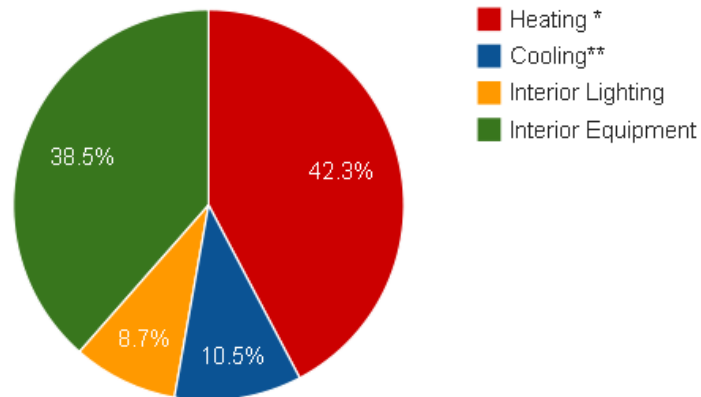


Credit: David Goldwasser / NREL

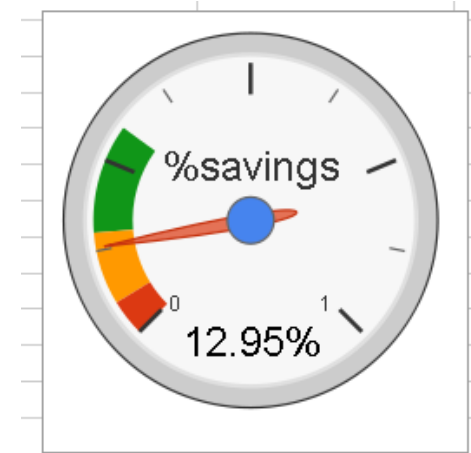
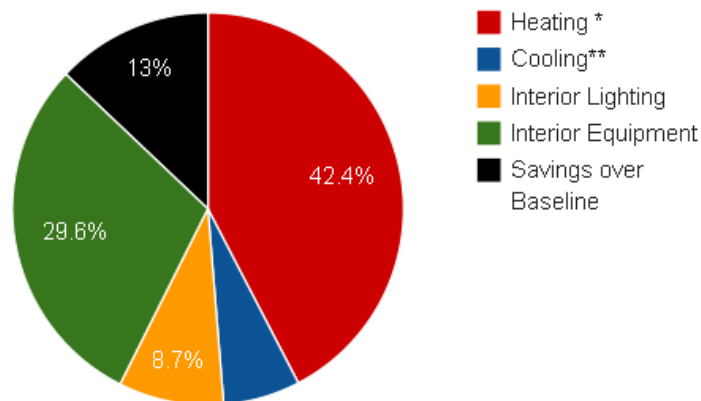
OpenStudio Demo

ABUPS's Comparison for Upgraded Kitchen Equipment

Baseline End Use Breakdown



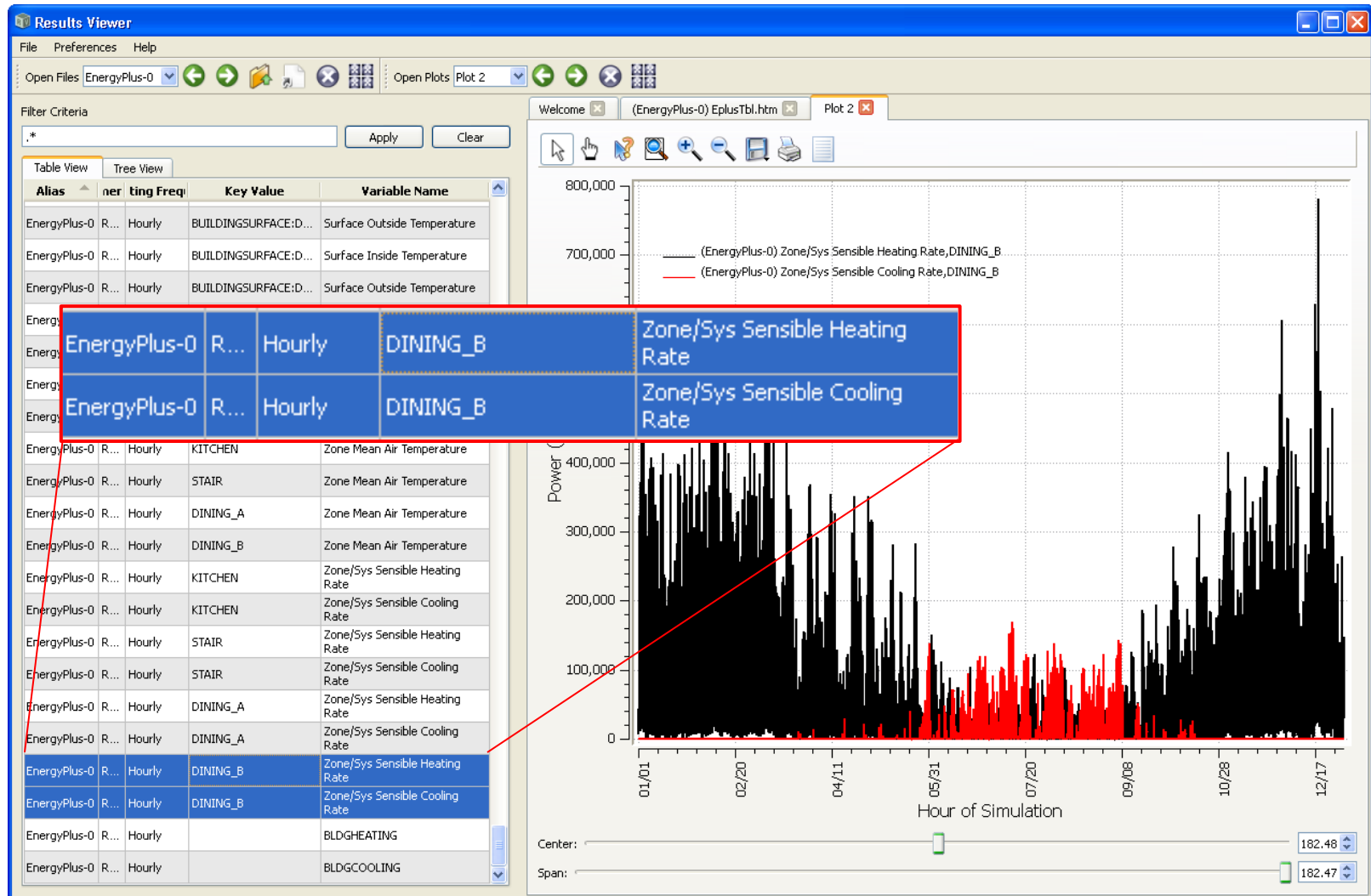
Proposed End Use Breakdown



Credit: David Goldwasser / NREL

OpenStudio Demo

Time-Series Simulation Data in OpenStudio ResultsViewer (Line Plot)



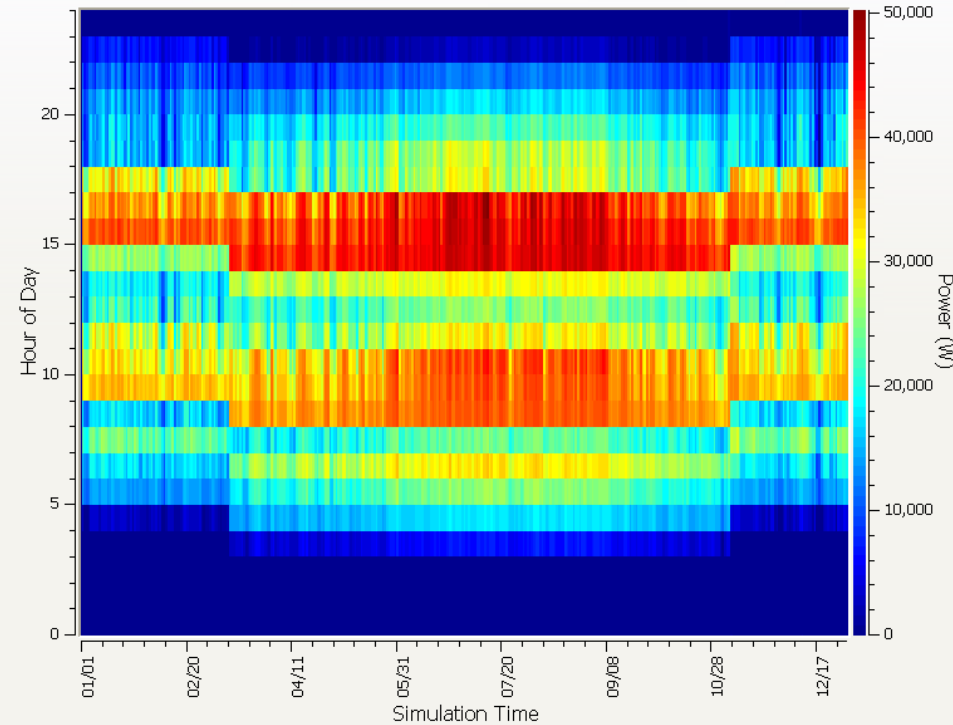
Credit: David Goldwasser / NREL

OpenStudio Demo

Time-Series Simulation Data in OpenStudio ResultsViewer (Flood Plot)

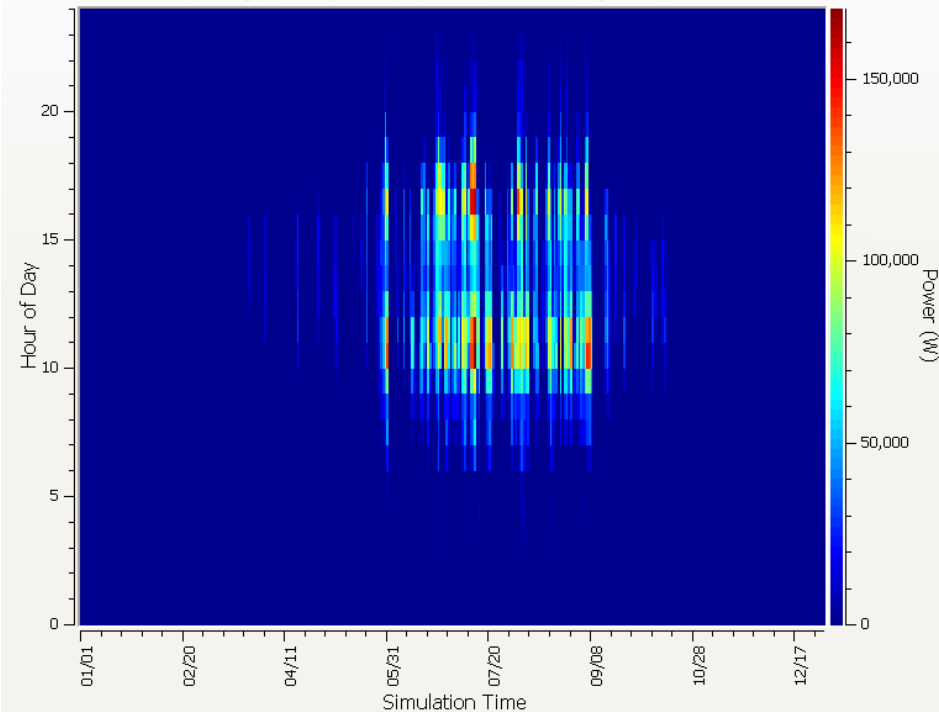
Kitchen - Sensible Cooling

(EnergyPlus-0) Zone/Sys Sensible Cooling Rate,KITCHEN



Dining - Sensible Cooling

(EnergyPlus-0) Zone/Sys Sensible Cooling Rate,DINING_B

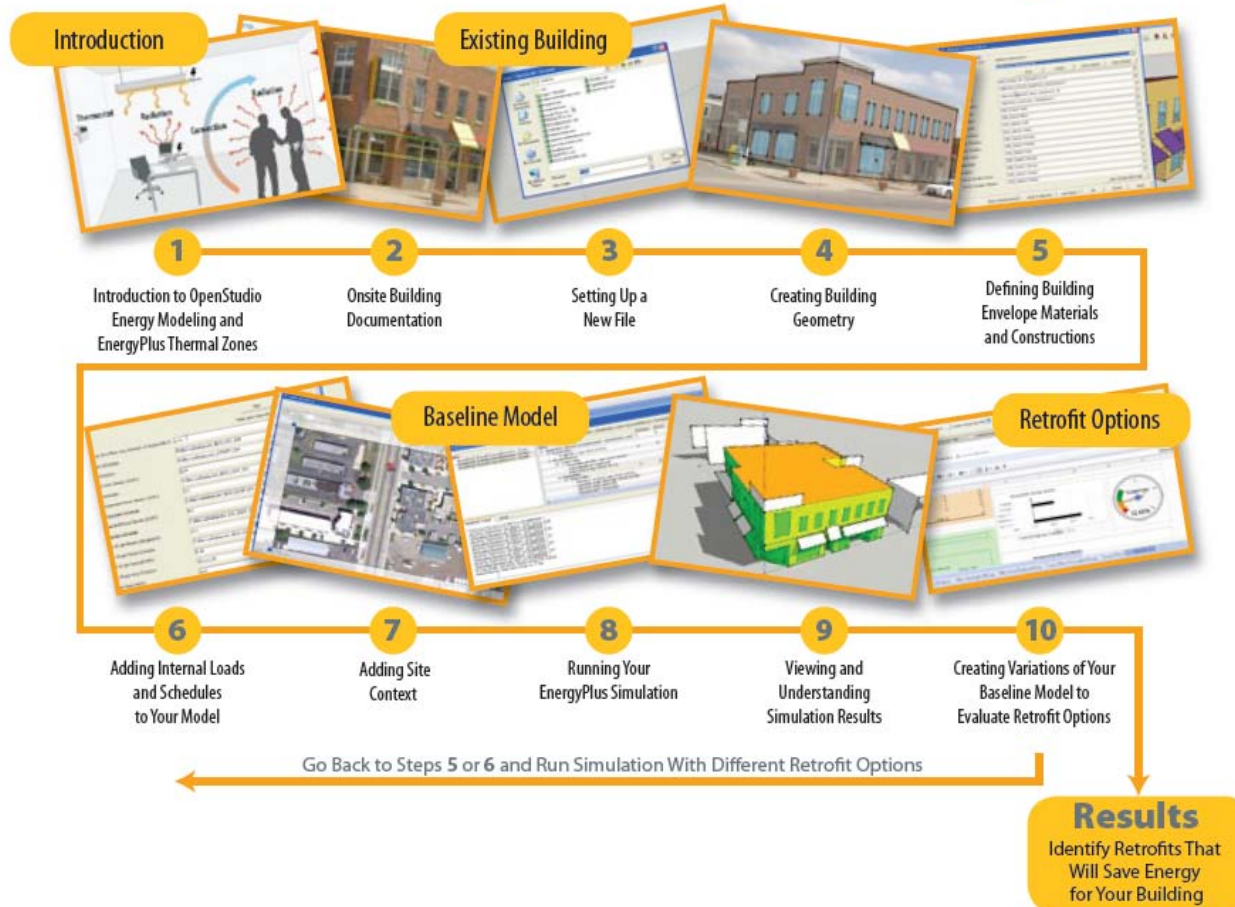


Credit: David Goldwasser / NREL

Retrofit Guide PDF and Videos

Use OpenStudio to Create Your Own Energy Model

 4-6 hours



<http://openstudio.nrel.gov/energy-modeling-retrofit-projects>

Credit: Marjorie Schott/ NREL

Typical Barriers to Using Simulation

Typical Barriers to Using Simulation

Some real, some perceived

- Complexity
- Time investment
- Experience required
- Lack of data
- Belief of inaccurate results

How to overcome?

- Training courses
- Conference proceedings (IBPSA)
- Energy modeling conferences
- User listservs (i.e. bldg-sim)
- Software documentation
- Design Guides
 - ASHRAE/AIA/DOE/IES/USGBC Advanced Energy Design Guide series
- Example files as starting point / wizards
 - Included with some software
 - DOE's commercial reference buildings



Credit: Nicholas Long / NREL

Inputs Needed for Whole-Building Simulation

- Weather Data
- Ground Temperatures
- Building Geometry
- Window Areas
- Constructions
- Ground Coupling
- Building Program / Thermal Zoning
- Plug Loads (Electric / Gas)
- Miscellaneous Electrical Loads
- People Activity
- Lighting Type
- Infiltration
- Daylighting Configuration
- Schedules
- HVAC Systems
 - Fans
 - Coils
 - Boilers
 - Chillers
 - ERV
 - PTHP/VAV/etc.
- Ventilation Requirements
- Exhaust Requirements
- HVAC Performance Data
- Control Sequences
- Temperature Set Points
- SWH / DHW
- Water Use
- Utility Rates

... and more

Typical Barriers to Using Simulation

A Solution to the Data Problem

The Building Component Library

<http://bcl.nrel.gov/>

Building Component Library



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OpenStudio | Google SketchUp Plug-in

OpenStudio includes a free plug-in for the Google SketchUp 3D drawing program. The plug-in makes it easy to create and edit the building geometry in your EnergyPlus input files. The plug-in also allows you to launch EnergyPlus simulations and view the results without leaving SketchUp.

You can add building components from this library into your SketchUp files and get more accurate and detailed analysis of your energy use.

1 2

New Content

	TV Sony KDL-52EX700 109
	TV Vizio VX32L-HDTV10A 24
	TV Vizio VX32L-HDTV10A 109
	TV Vizio VO420E 24

Popular Content

	yokima wa [727810 TMY2-24243] Annual Cooling (DB MWB) 1
	denverintlapco [725650 TMY3]
	denver-stapleton co [724690 TMY-23062]
	yokima wa [727810 TMY2-24243] Annual Cooling (DB MWB) 4

Developer Access



News

Initial Component Upload Complete

[more](#)

Browse By Category

 Air Sealing	 Boiler	 Central Air Conditioner	 Design Day	 Display	 Duct Insulation	 Duct Sealing
--	---	--	--	--	--	---

[View all component types](#)

Credit: David Goldwasser / NREL

The Building Component Library


How Components are Defined ...

- Taxonomy of components (tags)
 - Includes Windows, Walls, MELs, HVAC Systems, Fans, Utility Rates, Weather Files
 - Site manages synonyms, related terms, and the hierarchy
- Description of components (attributes)
 - Each component type has an “infinite” number of attributes
 - Defines the characteristics of the components
 - Length, width, location, HDD, U-Factor, SHGC, Volumetric Flow Rate, etc.
 - Costs
- Other metadata
 - Provenance (who submitted it, when, etc.)
 - Files (list of files associated with the component)
 - Videos, images (if applicable)

The Building Component Library

Building Component Library - Text Search

Building Component Library



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Filter by

Attributes








- Facade
- U-Factor
- Standard
- City
- License
- Latitude
- Vlt
- Standard Type
- Cdd10
- Cdd18
- Dewpoint
- Climate Standard Year
- Shgc
- Windspeed
- Max Drybulb Temperature
- Insulation Minimum R-value
- Hdd18
- Monthly Mean Db Temperature
- Longitude
- Water Main Calculation
- Construction Type
- Hdd10

26517 results

Show 10

Sort By Rating

Download Checked


	Yakima wa [727810 TMY2-24243] Annual Cooling (DB MWB) 1 Source: nlong - 04/09/11 Component Types: Design Day, Location-Dependent Component,	User rating: ★★★★★ Downloads: 7 Fidelity rating: 3	<input type="button" value="Download"/> <input type="checkbox"/>
	Large Office TSD Nonresidential 8A Door Syringing Source: nlong - 04/09/11 Component Types: Construction Assembly, Door, Fenestration, Construction Assembly,	User rating: ★★★★★ Downloads: 11 Fidelity rating: 3	<input type="button" value="Download"/> <input type="checkbox"/>
	Denver intl ap co [725650 TMY3] Source: nlong - 04/09/11 Component Types: Weather File, Location-Dependent Component,	User rating: ★★★★★ Downloads: 11 Fidelity rating: 3	<input type="button" value="Download"/> <input type="checkbox"/>
	Denver-stapleton co [724690 TMY-23062] Source: nlong - 04/09/11 Component Types: Weather File, Location-Dependent Component,	User rating: ★★★★★ Downloads: 70 Fidelity rating: 3	<input type="button" value="Download"/> <input type="checkbox"/>
	Yakima wa [727810 TMY2-24243] Annual Cooling (DB MWB) 4 Source: nlong - 04/09/11 Component Types: Design Day, Location-Dependent Component,	User rating: ★★★★★ Downloads: 1 Fidelity rating: 3	<input type="button" value="Download"/> <input type="checkbox"/>
	Colorado springs muni ap co [724660 TMY3] Source: nlong - 04/09/11 Component Types: Weather File, Location-Dependent Component,	User rating: ★★★★★ Downloads: 19 Fidelity rating: 3	<input type="button" value="Download"/> <input type="checkbox"/>
	Denver centennial golden nr co [724666 TMY3] Source: nlong - 04/09/11	User rating: ★★★★★ Downloads: 4	<input type="button" value="Download"/> <input type="checkbox"/>

Credit: David Goldwasser / NREL

The Building Component Library

Building Component Library - Facets

Building Component Library



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Filter by

Attributes

- Facade
- U-Factor

to

Range: 1.136 to 6.922
- Standard
- Vlt
- Standard Type
- Climate Standard Year
- Shgc

to

Range: 0.25 to 0.77
- Construction Type
- Construction
- Minimum Glazing Fraction
- Maximum Glazing Fraction
- Climate Zone







Component Types

- Construction Assembly (19)
- Fenestration (19)
- Window (14)

19 results

Show

Sort By


	ASHRAE Std189 Residential 4B Window Metal framing (entrance door) Source: nlong -04/09/11 Component Types: Construction Assembly, Window, Fenestration, Construction Assembly, User rating: Not yet rated Downloads: 0 Fidelity rating: 3	<input type="button" value="Download"/> <input type="checkbox"/>
	ASHRAE 90.1-2007 Residential 8A Window Metal framing (entrance door) Source: nlong -04/09/11 Component Types: Construction Assembly, Window, Fenestration, Construction Assembly, User rating: Not yet rated Downloads: 0 Fidelity rating: 3	<input type="button" value="Download"/> <input type="checkbox"/>
	ASHRAE 90.1-2007 Residential 7A Window Metal framing (entrance door) Source: nlong -04/09/11 Component Types: Construction Assembly, Window, Fenestration, Construction Assembly, User rating: Not yet rated Downloads: 0 Fidelity rating: 3	<input type="button" value="Download"/> <input type="checkbox"/>
	ASHRAE 90.1-2007 Residential 5B Window Metal framing (entrance door) Source: nlong -04/09/11 Component Types: Construction Assembly, Window, Fenestration, Construction Assembly, User rating: Not yet rated Downloads: 0 Fidelity rating: 3	<input type="button" value="Download"/> <input type="checkbox"/>
	ASHRAE 90.1-2007 Residential 6B Window Metal framing (entrance door) Source: nlong -04/09/11 Component Types: Construction Assembly, Window, Fenestration, Construction Assembly, User rating: Not yet rated Downloads: 0 Fidelity rating: 3	<input type="button" value="Download"/> <input type="checkbox"/>
	ASHRAE 90.1-2007 Residential 4B Window Metal framing (entrance door) Source: nlong -04/09/11 Component Types: Construction Assembly, Window, Fenestration, Construction Assembly, User rating: Not yet rated Downloads: 0	<input type="button" value="Download"/> <input type="checkbox"/>

Credit: David Goldwasser / NREL

The Building Component Library


Viewing Components

Building Component Library




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ASHRAE 90.1-2001 Residential B-8 Window fixed



Click to view more images

[View video](#)

Fidelity level: 

User Rating
☆☆☆☆
Your rating: None

Downloads: 0

Component Types:
[Construction Assembly](#)
[Window](#)


[Suggest a Type](#)

Attributes	
Standard	ASHRAE90.1-2001
Standard type	Residential
Climate standard year	ASHRAE 1999
Climate zone	B-8
Construction	Window
Construction type	fixed
U-Factor	6.515 Btu/ft ² F h
Shgc	0.19
Vlt	0.19
Facade	north
Minimum glazing fraction	0.4
Maximum glazing fraction	1

Source	
Files	
Version	6.0.0
File Name	ASHRAE90.1-2001_Residential_B-8_Window_fixed.idf
File Type	idf

Cost Data	
estimate	498.248 \$/m ²
estimate	\$/m ²
estimate	2.340 \$/m ²
estimate	0.000 \$/m ²
estimate	0.000 \$/m ²

Provenance	
nlong	September 30th, 2010

[Download Component](#)

Credit: David Goldwasser / NREL

The Building Component Library

Viewing Components

Building Component Library



ASHRAE 90.1-2001 Residential B-8 Window fixed



[Click to view more images](#)

[View video](#)

Attributes

Standard	ASHRAE 90.1-2001
Standard type	Residential
Climate standard year	ASHRAE 1999
Climate zone	B-8
Construction	Window
Construction type	fixed
U-Factor	6.515 Btu/ft ² F h
Shgc	0.19
Vlt	0.19
Facade	north
Minimum glazing fraction	0.4

Credit: David Goldwasser / NREL

Conclusions

Energy modeling is useful for evaluating designs in both new and retrofit projects.

OpenStudio can support energy modeling as an integrated part of the design process, from pre-design through post occupancy.

The Building Component Library makes it easier to find reliable and appropriate energy modeling input data.

Q & A

Thank You

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